CLAIMS

What is claimed is:

1. A control system that includes a field oriented controller that receives a torque command and that generates phase voltages for an electric machine including a rotor and a stator, comprising:

a first transformation module that receives stator terminal currents from the electric machine and that generates d-axis and q-axis stationary frame currents;

an open loop flux observer that receives d-axis and q-axis stationary frame voltage commands and an estimated rotor angular velocity and that includes:

a vector cross product calculator that generates an error signal that is proportional to an angular difference between an estimated stator flux and a computed stator flux; and

a proportional integral controller that generates an estimated rotor angular position based on said error signal; and

a second transformation module that receives said d-axis and q-axis stationary frame currents, said estimated rotor angular position and said estimated rotor angular velocity and that generates d-axis and q-axis synchronous reference frame feedback currents that are output to the field oriented controller.

2. The control system of Claim 1 wherein said electric machine is a permanent magnet electric machine.

3. The control system of Claim 1 wherein said open loop flux observer includes:

a d-axis voltage drop calculator that calculates a d-axis stator voltage drop due to a resistance of the stator;

a q-axis voltage drop calculator that calculates a q-axis stator voltage drop due to said resistance;

a first summer that generates a d-axis back EMF by calculating a first difference between said d-axis stationary frame voltage command and said d-axis stator voltage drop; and

a second summer that generates a q-axis back EMF by calculating a second difference between said q-axis stationary frame voltage command and said q-axis stator voltage drop.

4. The control system of Claim 3 wherein said open loop flux observer includes:

a first low pass filter that receives an electrical angular velocity estimate and said d-axis back EMF and that generates a d-axis stator flux linkage value; and

a second low pass filter that receives said electrical angular velocity estimate and said q-axis back EMF and that generates a q-axis stator flux linkage value.

5. The control system of Claim 4 wherein said vector cross product calculator includes:

a sine function generator that generates a sine value based on an estimated stator flux angular position;

a cosine function generator that generates a cosine value based on said estimated stator flux angular position;

a first multiplier that multiplies said sine value by said d-axis stator flux value to generate a first product;

a second multiplier that multiplies said cosine value by said q-axis stator flux value to generate a second product; and

a first difference circuit that generates an error signal that is based on a difference between said first product and said second product.

6. The control system of Claim 1 further comprising a low pass filter that filters said estimated rotor angular velocity.

7. The control system of Claim 1 wherein said open loop flux observer further includes:

a load angular position circuit that generates a load angular position;

a derivative calculator that calculates a derivative of said load angular position; and

a summing circuit that generates a stator flux angular velocity by summing said load angular position derivative and said estimated electrical angular velocity.

8. The control system of Claim 7 wherein said open loop flux observer further comprises an integrator that integrates said stator flux angular velocity to generate a stator flux position.

9. The control system of Claim 8 further comprising a second difference circuit that generates said estimated angular rotor position based on a difference between said stator flux position and said load angular position.

10. An open loop flux observer for a permanent magnet electric machine, comprising:

a first back EMF calculator that calculates a d-axis back EMF;

a second back EMF calculator that calculates a q-axis back EMF;

a first low pass filter that receives said d-axis back EMF and an estimated electrical angular velocity and that generates a d-axis stator flux linkage;

a second low pass filter that receives said q-axis back EMF and said estimated electrical angular velocity and that generates a q-axis stator flux linkage;

a vector cross product calculator that receives said d-axis stator flux linkage and said q-axis stator flux linkage and that generates an error signal; and

a proportional integral controller that generates an estimated rotor angular position based on said error signal.

11. The open loop flux observer of Claim 10 wherein said d-axis back EMF calculator comprises:

a d-axis stator voltage drop calculator that calculates a d-axis stator voltage drop due to stator resistance; and

a first summer that generates said d-axis back EMF by generating a first difference between said d-axis stationary frame voltage command and said d-axis stator voltage drop.

12. The open loop flux observer of Claim 11 wherein said q-axis back EMF calculator comprises:

a q-axis stator voltage drop calculator that calculates a q-axis stator voltage drop due to said stator resistance; and

a second summer that generates said q-axis back EMF by generating a second difference between said q-axis stationary frame voltage command and said q-axis stator voltage drop.

13. The open loop flux observer of Claim 10 wherein said vector cross product calculator includes:

a sine function generator that generates a sine value based on an estimated stator flux angular position;

a cosine function generator that generates a cosine value based on said estimated stator flux angular position;

a first multiplier that multiplies said sine value by said d-axis stator flux value to generate a first product;

a second multiplier that multiplies said cosine value by said q-axis stator flux value to generate a second product; and

a difference circuit that generates an error signal that is based on a difference between said first product and said second product.

14. The open loop flux observer of Claim 13 further comprising a low pass filter that filters said estimated electrical angular velocity.

15. The open loop flux observer of Claim 10 further comprising a load transient compensating circuit.

16. The open loop flux observer of Claim 15 wherein said load transient compensating circuit includes:

a load angular position circuit that generates a load angular position;

a derivative calculator that calculates a derivative of said load angular position; and

a summing circuit that generates a stator flux angular velocity by summing of said load angular position derivative and said estimated electrical angular velocity.

17. The open loop flux observer of Claim 16 wherein said open loop flux observer further comprises an integrator that integrates said stator flux angular velocity to generate a stator flux position.

18. The open loop flux observer of Claim 17 further comprising a difference circuit that generates said estimated angular rotor position based on a difference between said stator flux position and said load angular position.